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NEURAL NETWORK SYSTEM FOR SELECTION OF TABLE TENNIS EQUIPMENT

The article examines the optimization of search processes and the relevance of the use of artificial neural networks for the selection of table tennis equipment. With the help of neural networks, it is possible to solve any task. The problem is only to make the right choice of architecture and structure of the neural network, the algorithm of its operation and to formalize the source data, the result and the corresponding transformation. The problem of clustering the table tennis equipment market is considered.

The result of the research has become the creation of information-analytical system "Neuro TT" for the analysis of the table tennis equipment market and the possibility of selecting the optimal combination of rubbers and blade. The structure of such a neural network system has been developed. It consists of three information banks, which contain information about the properties of rubbers and blades, as well as known combinations of rubbers and blades.

The use of such a system will allow to forecast the development trends of the table tennis equipment market, manufacturers to plan and change the structure of production, buyers (players) and sellers to fully meet the information needs.

Keywords: *neural network, optimization process, clustering, neural network system, algorithm.*

Introduction. Current trends of table tennis equipment market are caused by a number of reasons. A fast development of innovation technologies and their usage in everyday life is an integral part of a modern society. An automation of a wide range of human activities is observed. At the same time, the interest in physical culture and mass sports is increasing, which leads to mass activity of the population and popularization of game sports and in particular table tennis. This sport for playing at a high level does not require complex organization and significant financial costs. Table tennis covers different age categories and is an excellent means of active recreation, strengthening the body and keeping it in constant tone. That is why table tennis is so popular in the world. This is particularly evident by the record number of countries participating in the World Table Tennis Championships (141 countries of which 80 are men's and 61 are women's teams). A prerequisite for a high level of training in this game is the correct selection of a combination of rubbers and a blade. It is also necessary to take into account the fact that the rubbers and the blade have their own properties that affect the game to one degree or another. In addition, there is a problem of a successful combination of sports equipment and playing style of a table tennis player. Thus, the variety of table tennis equipment makes the selection of the right combination of rubbers and a blade quite a difficult choice for a player.

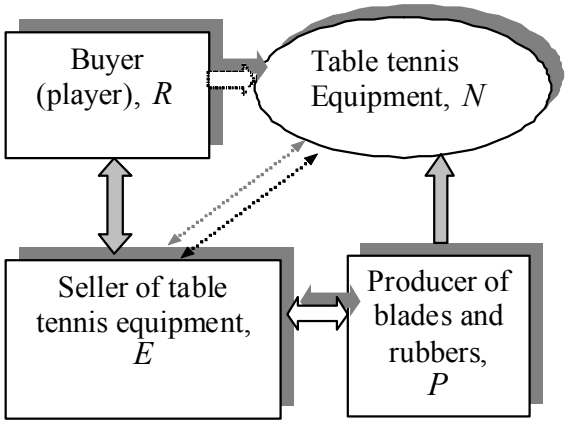

Figure 1 – The structure of the table tennis market

Table tennis market structure and its optimal management can be represented thus (figure 1 and figure 2).

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Research problem statement. *The purpose of the research* is to develop a neural network system for the selection of the right combination of rubbers and a blade. It is necessary to develop a structure, principles of operation of such a neural network system. The system being developed should offer the player several variations of rubbers combinations for the existing blade that would suit the player's style of play and requirements. Also system should help the player to choose the right blade and rubbers if necessary [1-2].

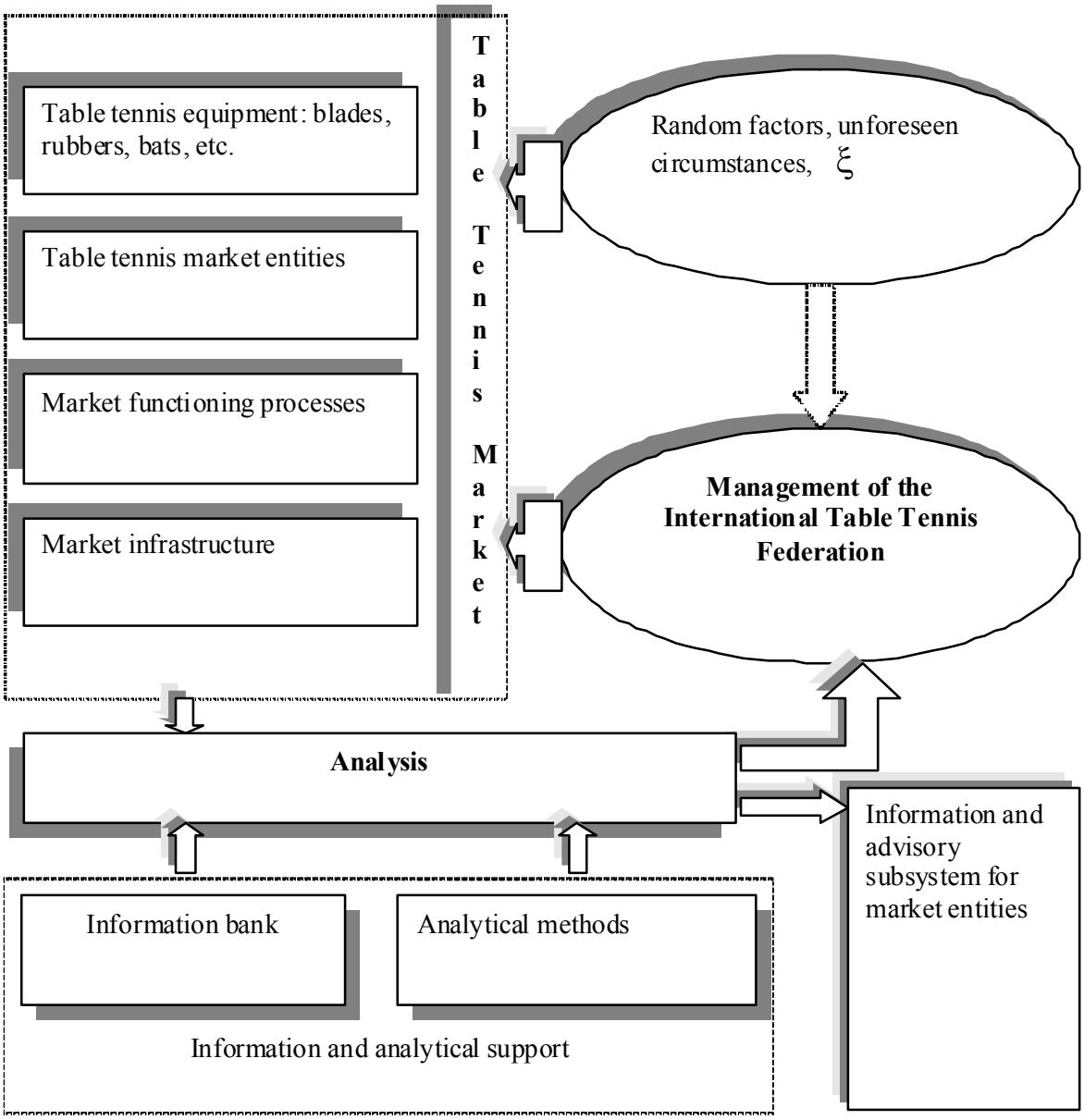

Figure 2 – Optimal management of the table tennis market
Developed by the authors

The neural network system needs to be filled with such content that would contribute to the competent formulation of the problem, the choice of the optimal strategy for its solution, would reflect the decision-making style in a given subject area, as well as the model of this area itself. Thus, this intelligent system must have the properties of adaptation and self-organization. It will integrate the knowledge of a mathematician, a programmer and an expert on table tennis equipment. Its focus on a specific player, who has his own ideas on the

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interpretation, assessment, processing and analysis of information, will significantly improve the quality of solutions, and the neural network system itself will become an intellectual partner of a person in solving the problem of choosing table tennis equipment.

The developed system should provide analytical services to the players and classify the rubbers and blades according to the given standards, determine the priority factors and the degree of their influence on the properties of the finished racket (the combination of rubbers and a blade).

To implement the developed neural network system, a client-server architecture is used, when the database is found on the server, and the software and analytical support on the workstation. Such an organization significantly reduces the time required for the selection of equipment for the player and its information support.

Analysis of recent research sources. Analysis of literary sources indicates that most often tasks with the selection of table tennis equipment can be solved by such methods as: statistical analysis, search by analogy, search trees and soft computing.

Modern scientific developments of national and foreign scientists are focused on combining technical and sports areas to automate work and obtain high-quality results. Renowned table tennis coaches and experts R. V. Barchukova, V. M. Bogushchas, O. V. Matitsin argue that now it is possible to achieve significant results in the game by optimizing the selection of the equipment [4].

The inclusion of table tennis in the program of the Olympic Games in 2001 provoked a rapid growth in the sports arena and served as an impetus for the development of this sport. Table tennis is characterized as an analytical sport with a variety of playing techniques and many tactical patterns. A modern table tennis player must have a high general physical training and psychological one, which is no less important.

The use of neural networks in various fields is relevant, as evidenced by the emergence of a significant number of publications on this topic, in particular, a number of new publications can be found in the works of J. D. Cowan, C. Koch, G. C. Fox, J. G. Koller et al.

Analysis of a wide range of tasks, that are solved by the subjects of the table tennis market for market processes of both an objective and a subjective nature, indicates the need to create information services and analytical support.

Significant power of the set of initial data [3], their diversity, subjective nature of origin, taking into account the possibility of force majeure circumstances and the probability of their occurrence, determining the degree of response to minimize losses do not allow adequate analysis of information within traditional statistical and integro-differential methods.

One of the main features that must be taken into account when developing models and methods of analysis is the variety of factors and the high power of many of their values. Invariant to such features is modeling based on the use of neural networks, the result of which, although it will not be expressed in dependence in the analytical form, but will solve the problem of analysis and selection of table tennis equipment. Using an artificial neural network (ANN) for identification, the researcher is not limited by any conditions that are inherent in other analytical methods.

Artificial neural networks and algorithms for their functioning. The most acceptable in the selection of table tennis equipment can be statistical methods, which include correlation, regression, and factor analysis. Each of them is based on the calculation of average characteristics, which when modeling real practical situations, often give incorrect results. Using these methods, determine the existence of a linear relationship between factors, calculate the equation of multiple linear dependence (for table tennis equipment between parameter z which takes into account the speed, rotation and control and factors $x = (x_1, x_{2,} ... x_n)$ that describe the properties of the bat):

$$z = a_0 + \sum_{i=1}^{n} a_i x_i , \qquad (1)$$

where $a_i, i = \overline{0,n}$ – weights that determine the most important factors and the degree of influence of each of them on the resulting indicator and can be used to test the hypothesis of the impact of qualitative characteristics on quantitative ones.

A neural network with a traditional straight-line architecture with two layers of

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weights looks like this [3]. The operation of an ANN with an inverse error propagation algorithm [5] is based on two technologies: the first one is designed to minimize the objective function and is based on gradient optimization methods [6]; the second one is also aimed at minimizing, but already components of the overall objective function in the opposite direction of signal propagation, and is based on the inverse propagation of the error. The target function for all networks is as follows:

$$E = E(W,\eta) = \frac{1}{kp}\sum_{i=1}^{k}\sum_{j=1}^{p}(T_i^j - Y_i^j(W,\eta))^2, \quad (2)$$

where T_i^j is the tabular value of the i-th result characteristic for the j-th input image, $Y_i^j(W,\eta)$ is the calculated ANN value, W is the array of weights, η is the aggregate vector of other network and learning parameters.

The advantages of ANN with an inverse error propagation algorithm are that according to the method of the fastest descent, the target function decreases with each step and necessarily reaches its minimum, and the learning process is relatively fast. At the same time, the efficiency of ANN with an inverse error propagation algorithm, as well as any iterative algorithm, depends on the choice of the starting point (reference solution, which is the initial set of weights) and the step of finding a solution.

A representative of networks with a direct learning algorithm is an RBF network. The speed of training and absolute accuracy of identification at training points testify in its favor. The disadvantages are that in large-scale problems it is necessary to calculate inverse matrices, which are often poorly conditioned, and low accuracy of forecasting at points that do not belong to the internal field of study.

The Kohonen network (or one of its variants is the self-organized Kohonen map) is often used to solve clustering problems. As a result of learning the Kohonen network, a set of maps is built, each of which is a two-dimensional grid of nodes placed in multidimensional space. The task of its training is to adjust the activation coefficients so as to activate the same neuron for similar vectors at the input. The weights are adjusted by an iterative algorithm, in which various heuristic techniques are used for adequate training, which allow to obtain a stable and suboptimal solution with a minimum number of iterations.

As it has been found that the usage of the Kohonen neural network is the most appropriate way to solve the problem of table tennis equipment selection. The use of this neural network allows quickly to solve clustering problems and to find more accurate solutions in comparison with the options considered.

The task of clustering the table tennis equipment market. Important for the analysis of table tennis equipment market is the problem of general clustering, which is formulated as follows. Let $\Psi_i, i = \overline{1,m}$ table tennis bats, which are presented in the information bank. Each bat is characterized by a set of parameter values $(x_1^i, x_2^i, ..x_n^i), i = \overline{1,m}$. A priori, the analyst specifies the number of clusters K. Usually $K \in \{3,4,5,6,7\}$. To form clusters, the initial data must be reduced to a dimensionless form. If in the further research it is not supposed to study bats with extreme values of parameters, that is, there is no such Ψ_i, $i > m$ and such $j \in \{1,2,..,n\}$ that $x_j^i \notin \Omega$, where Ω_j – set of values of the j-th factor, then the rationing formula is as follows:

$$X' = \frac{X - X_{\min}}{X_{\max} - X_{\min}}. \quad (3)$$

If such a possibility is not excluded, the law of rationing may be one of the following:

$$X' = \frac{X - m}{\sigma}, X' = \frac{1}{1 + e^{-x}}, \quad (4)$$

where m – mathematical expectation (in the calculations we replace it with the mean value), σ – standard deviation (in the calculations we use the selective standard deviation). It is possible that the normalization is performed using the composition of two transformations (4).

Without limiting the generality, we assume that $X_j \in \Omega_j = [0,1]$, $j = \overline{1,n}$. A cluster is a group of objects Ξ, such that the mean square of the intragroup distance to the center of the group

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is less than the mean distance to the total center in the initial set of objects, i.e. $\overline{d}_{\Xi}^2 < \sigma^2$, where

$$\overline{d}_{\Xi}^2 = \frac{1}{N}\sum_{X_i \in \Xi}(X_i - \overline{X}_{\Xi})^2, \overline{X}_{\Xi} = \frac{1}{N}\sum_{X_i \in \Xi} X_i. \quad (5)$$

The task of clustering is to find a function $\phi(i)$ that determines the number class on the index and minimizes the sum of proximity measures:

$$\min \sum_{i=1}^{m}\sum_{\substack{j=1 \\ j>i}}^{m} \left\| \Psi_i^{\phi(i)} - \Psi_j^{\phi(j)} \right\| \quad (6)$$

given that

$$\sum_{v=1}^{K}\sum_{i=1}^{m_v} \chi(\Psi_i \in v - th\, cluster) = m, \quad (7)$$

where m_v is the number of bats in the v-th cluster, $\chi(R) = \begin{cases} 1, & if \quad R \quad is \ true, \\ 0, & otherwise \end{cases}$.

The structure and construction features of the neural network system. Wide implementation and definition of the advantages of data mining technologies [7], [8] knowledge discovery in databases (KDD) [9], OLAP gives all grounds for the use of ANN.

Functional load of the neural network system «NEURO TT», divided into several fragments, which are determined by the entity working with the system (figure 3). The information base is made by an information bank, which is three-component and includes a supply bank (IB1), a demand bank (IB2) and a bank that contains background information (IB3).

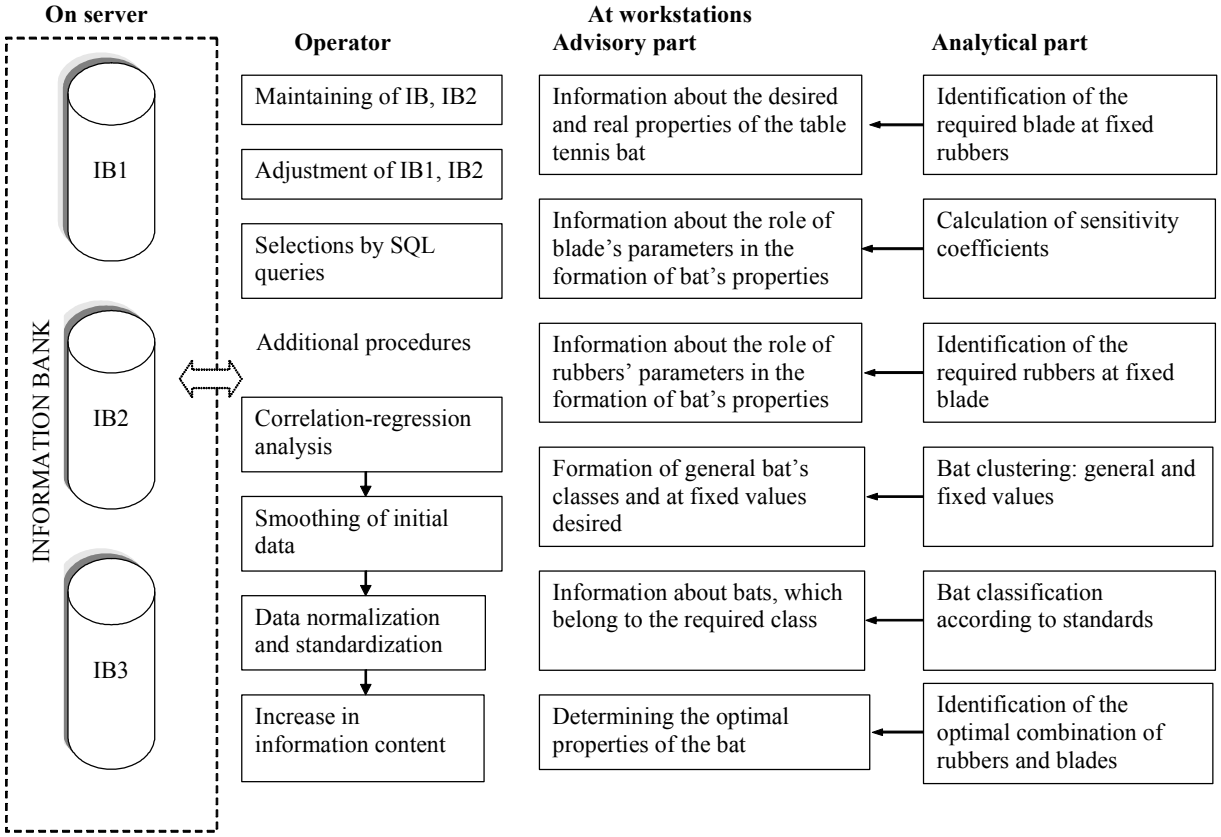

Figure 3 – Structural scheme of the neural network system "NEURO TT"

All components are located on the server and are informationally independent of each other. Data entry and correction are performed by the operator. If necessary, the operator can obtain the necessary information from the tables of the information bank using SQL-queries.

The initial data of the research will be known as the content of two information banks, the first of which contains information about the existing bats, which can be obtained from three sources [10-12], , the second – information about the desired object of purchase. The difference

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between IB1 and IB2 is that it contains unambiguous information, and certain fields contain data represented by membership functions [13] or intervals.

As is known, a fuzzy set $\tilde{A}$ on a universal set U is a set of pairs $(u, \mu_A(u))$, where $\mu_A(u)$ is a measure of the element $u \in U$ belonging to a fuzzy set $\tilde{A}$. The membership function is a function that allows to calculate the degree of belonging of an arbitrary element from a universal set to a fuzzy set.

The values of the information bank fields have different formats: symbolic, numeric, integer, boolean, dates. Procedures for bringing them to a form adapted for analysis using computer technology, are developed in [14], [15]. The information that comes directly to the input of the computational algorithm is numerical.

Discussion of research results. Summarizing the above, we note that the algorithm of search, selection according to certain criteria of table tennis equipment and the process of processing the obtained source data in an environment of great diversity of information occupies an important place in modern society. This is due to the fact that previously known search methods on the Internet are becoming less effective due to the rapid increase in the number of information platforms. The process of automation of search engines allows you to faster and more efficiently perform search queries according to certain criteria.

The developed neural network system "NeuroTT" allows you to more effectively perform search queries on certain criteria of compliance and take into account current changes in the information society. As a result of research and comparison with existing similar systems, it becomes clear that the development and use of effective search engines like NeuroTT, focused on the needs of users of a particular professional environment is of considerable scientific interest.

Conclusions. Thus, neural network systems form a new high-tech direction in the development of most branches of science and are fundamental in practical use. The current state of the table tennis market and the almost complete absence of methods of analysis for the selection of equipment indicate the need for the development of information and analytical systems.

The developed "Neuro TT" system will allow for a player to obtain all the necessary information support. "Neuro TT" will integrate the knowledge of a mathematician, a programmer and an expert on table tennis equipment. It's focused on a specific player, who has his own ideas on the interpretation, assessment, processing and analysis of information.

Such systems will operate on a single information base of table tennis equipment, allowing to forecast the market of equipment trends and prospects, manufacturers to plan and change the structure of production, as well as sellers and buyers to fully meet the information needs.

Prospects for further research of optimization processes in the selection of equipment for table tennis is the development of the theory of artificial neural networks and the practical implementation of existing methods.

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НЕЙРОМЕРЕЖЕВА СИСТЕМА ПІДБОРУ ІНВЕНТАРЯ ДЛЯ НАСТІЛЬНОГО ТЕНІСУ

У статті досліджується питання оптимізації пошукових процесів та актуальність використання штучних нейронних мереж для підбору інвентаря для настільного теннісу. Проводиться аналіз останніх публікацій в обраній темі та розглядаються переваги штучних нейронних мереж порівняно з традиційними видами знаходження рішень. Визначаються переваги використання комп'ютерних технологій з метою автоматизації процесів підбору інвентаря для настільного тенісу.

За домопомгою нейронних мереж можна розв'язати будь-яку задачу. Проблема полягає лише у тому, щоб здійснити правильний вибір архітектури та структури нейронної мережі, алгоритму її функціонування та здійснити формалізацію вихідних даних, результату та відповідного перетворення. В роботі розглядаються варіанти різних побудов штучних нейронних мереж і алгоритми їх функціонування з метою вибору оптимального алгоритму. Аналіюються недоліки та переваги мереж з алгоритмом оберненого поширення похибки, RBF (штучних нейронних мереж із радіально-базисними активаційними функціями) та карти Кохонена. В статті також розглянуто задачу кластеризації ринку інвентаря для настільного тенісу.

Результатом дослідження стало створення нейромережевої інформаційно-аналітичної системи «Neuro TT» для аналізу ринку інвентаря настільного тенісу з можливістю підбору оптимального поєднання накладок і основи.

Розроблено структуру такої нейромережевої системи. Вона складається з трьох інформаційних банків, в яких міститься інформація про властивості основ і накладок, а також відомі комбінації таких поєднань накладок і основ. Елементи системи розташовуються на сервері і є незалежними один від одного.

Використання такої системи дасть змогу передбачати тенденції розвитку ринку інвентаря для настільного тенісу, виробникам планувати та змінювати структуру виробництва, покупцям (гравцям) та продавцям повністю задовольнити інформаційні потреби.

Ключові слова: *нейронна мережа, процес оптимізації, кластеризація, нейромережева система, алгоритм.*

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